AD-A166 088 EFFECT OF INTERFACIAL PHENOMENA ON CONTACT LINE HEAT TRANSFER I(U) RENSSELAER POLYTECHNIC INST TROY NY DEPT OF CHEMICAL AND ENVI P C WAYNER 20 OCT 85 1/1

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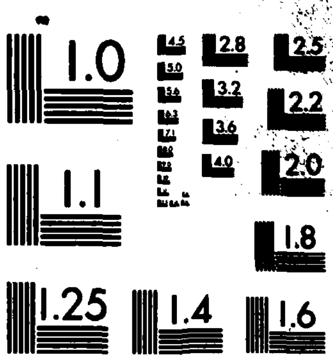

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The heat transfer characteristics of the contact line region of an evaporating thin liquid film were studied experimentally and theoretically. The effects of composition and temperature gradients on surface shear were analyzed and the results were successfully compared with previously reported experimental trends. The use of a constant vapor pressure boundary condition allowed the relative effects of surface tension, composition and temperature on fluid flow to be mapped.

A small heat transfer cell was designed, built and used on the scanning stage of a scanning microphotometer. The unique use of a microphotometer allows the microscopic details to be measured. The preliminary results are being analyzed to evaluate the effect of capillarity on the evaporating meniscus in heat pipes. Additional development work on the heat transfer cell is required. Modeling studies are being extended. keywords

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2. STATEMENT OF RESEARCH OBJECTIVES

The following figure which was taken from our previously submitted "Three Page Abstract" outlines our general three year objectives.

Figure 1

INTERFACIAL HEAT TRANSFER
CONTACT LINE REGION

GOAL

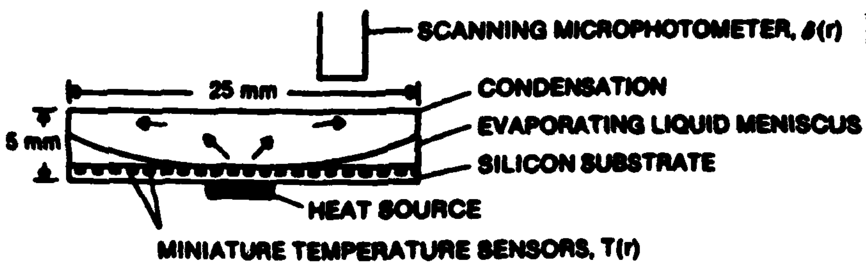
UNDERSTANDING OF TRANSPORT MECHANISMS IN EVAPORATING THIN LIQUID FILM (THICKNESS $< 10^{-5}$m)

GENERAL PRINCIPLE

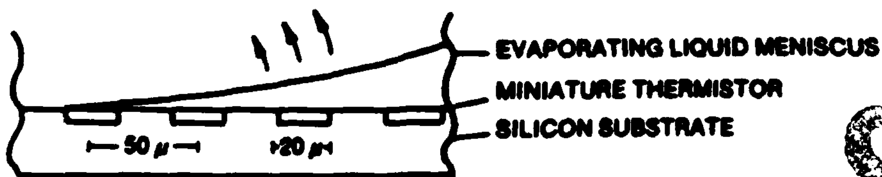
HEAT, MASS, AND MOMENTUM TRANSFER ARE CONTROLLED BY INTERFACIAL PHENOMENA RESPONDING TO GRADIENTS IN THE THICKNESS, TEMPERATURE AND CONCENTRATION

TECHNIQUES

1. MEASURE LIQUID THICKNESS PROFILE, $\delta(r)$, AS A FUNCTION OF BULK CONCENTRATION AND EVAPORATION RATE IN NEW CIRCULAR MINIATURIZED HEAT TRANSFER CELL USING SCANNING MICROPHOTOMETER.



2. MEASURE SUBSTRATE TEMPERATURE PROFILE, T(r), USING SMALL TEMPERATURE SENSORS.



3. COMBINE THE FOLLOWING CONCEPTS INTO HEAT TRANSFER SUCTION POTENTIAL MODEL: DISJOINING PRESSURE, FLUID MICROSTRUCTURE, SURFACE TENSION, APPARENT CONTACT ANGLE, $\delta(r)$, T(r).

3. STATUS OF RESEARCH

The scientific accomplishments of the first year are listed in Figure (2) and detailed in the following paragraphs.

1) Design and Build a New Heat Transfer Cell

A new small circular heat transfer cell was designed and built during the first year of the grant. A cross-sectional diagram of the cell is presented in Figure (2) and photographs of the cell are presented in Figures (3) and (4). The use of a small circular design eliminates the edge effects and reduces extraneous bulk effects. In this way we can focus on the heat transfer processes occurring in the contact line region. The interference fringes which result from the interference of the light waves reflected from the liquid-vapor interface with those reflected from the liquid-solid interface will be scanned "in-situ" with a scanning microphotometer. As described in Refs. [1,2], the measured fringe pattern gives the thin film thickness profile which can then be used to obtain the capillary pressure and the disjoining pressure gradients.

2) Test the Cell Design by Obtaining Heat Transfer Data Using a Mixture

The heat transfer cell is currently being tested for its response to the following variables: the volume of liquid charge, the external heat input, the bulk liquid composition, the external heat sink, and the level of non-condensibles in the vapor space. We note that since the cell is passive in that the interfacially induced flow rates are controlled by the temperature distribution on the surface of the cell (external heat input and external heat sink) the selection of the cell dimensions and the operating variables are critical. Our initial tests indicate that the cell design dimensions are approximately correct

in that the internal flow fields appear desirable. The preliminary data obtained using decane and hexane are being analyzed to determine the general operating caharacteristics of the cell. During these preliminary studies small deficiencies in the cell design are being identified and corrected: for example, the most desirable o-ring from a contamination point of view is not sufficiently compressible to allow clearance between the microscope objective and the cell window. In addition, we are still in the process of developing desirable small temperature sensors. A considerable portion of our current effort is focused on this development.

3) Develop Small Temperature Sensors

In the photograph in Figure (4) small lines can be observed. These are leads that are attached to small thermistors ($20\mu \times 20\mu$ Au - Al_2O_3 cermets) located on the substrate surface. Unfortunately these particular thermistors were not successful because their resistances were too high and they were also found to be too sensitive to minor variations in the light intensity in the room. In addition, the cermet step heights of 1×10^{-6} m and their porous nature cause minor variations in the meniscus profile. However, the work on these cermets has given us vital experience and does demonstrate the direction of our research. Work on the development of SiC thin film thermistors continues.

4) Modeling of Suction Potential at the Contact Line

In general, the physicochemical phenomena associated with fluid flow in an evaporating thin film of an ideal binary mixture in the contact line region are being modeled. Within these studies, the effect of composition and temperature gradients on surface shear needs to be evaluated. Using a constant vapor pressure boundary condition based on Raoult's Law, significant new insights con-

cerning the effect of liquid composition on enhanced fluid flow due to surface shear in the contact line were developed. The results were successfully used to qualitatively describe the trends experimentally observed in previous experimental studies [3,4].

The resulting equation for the mass flow rate given in Ref. [3] is

$$\Gamma = \frac{\delta^3}{3\nu}[\underbrace{1.5\delta^{-1}\sigma'}_{(I)} + \underbrace{\delta^{-n}B'}_{(II)} + \underbrace{K\sigma'}_{(III)} + \underbrace{\sigma K'}_{(IV)} - \underbrace{nB\delta^{-(n+1)}\delta'}_{(V)} + \underbrace{\rho g\delta'\cos\theta}_{(VI)} + \underbrace{\rho g \sin\theta}_{(VII)}] \quad (1)$$

wherein:

δ[=] film thickness
σ[=] surface tension
B[=] dispersion constant
θ[=] angle of inclination
K[=] curvature
ρ[=] density
g [=] gravitational constant

The prime refers to differentiation with respect to x. In this equation Terms (I-III) are functions of the temperature and concentration gradients, whereas Terms (IV-VII) are functions of the film profile. The significance of Ref. [3] is that additional insights concerning the conditions under which Terms (I-III) are important were developed. Although the film profile can be easily measured optically, the concentration and temperature gradients in a region less than 1 mm in length cannot be easily obtained experimentally. Therefore, extensive modeling of the fluid flow mechanisms dependent on the concentration and temperature gradients is needed. We note that although the new temperature sensors will allow the temperature field to be measured much more accurately than before some modeling of the temperature gradient will always be necessary. The model presented in Ref. [3] was primarily concerned with Terms (I-III). The results

presented in this reference demonstrated that the effect of surface shear on fluid flow can change sign in a distilling thin film as it flows towards the heat source along a constant vapor pressure line when $\sigma_2 > \sigma_1$ (subscript 2 refers to the less volatile component of a binary mixture). Assuming that the flow starts in a region where surface shear enhances the flow towards the heat source, $\frac{d\sigma}{dT} > 0$, a composition is reached in the flowing film at which flow reversal can occur in the film. The location of the sign reversal is a function of the concentration, the temperature level, and the difference in the surface tensions of the components of the binary mixture. Confirmation of this prediction in a designed set of experiments would verify the use of a constant vapor pressure boundary condition in the model. In addition the approximate value of the zones of minimum surface shear would be known. This would then allow a set of conditions to be selected so that the effect of these terms would be minimum in experiments designed to evaluate Terms (IV & V). Previously, these conditions were not quantitatively known to this degree. The use of Eq. (1) to select a mixture of alkanes for study during the second year is progressing.

[1] Cook, R., Tung, C.Y. and Wayner, P.C. Jr., "Use of Scanning Microphotometer to determine the Evaporative Heat Transfer Characteristics of the Contact Line Region," ASME Journal of Heat Transfer, 103, 325-330, 1981.

[2] Wayner, P.C. Jr., Tirumala, M., Tung, C.Y. and Yang, J.H., "Fluid Flow in the Contact Line Region of a Mixture of Alkanes: 98% Hexane - 2% Octane," AIAA 18th Thermophysics Conference, Montreal, Canada, June 1-3, 1983.

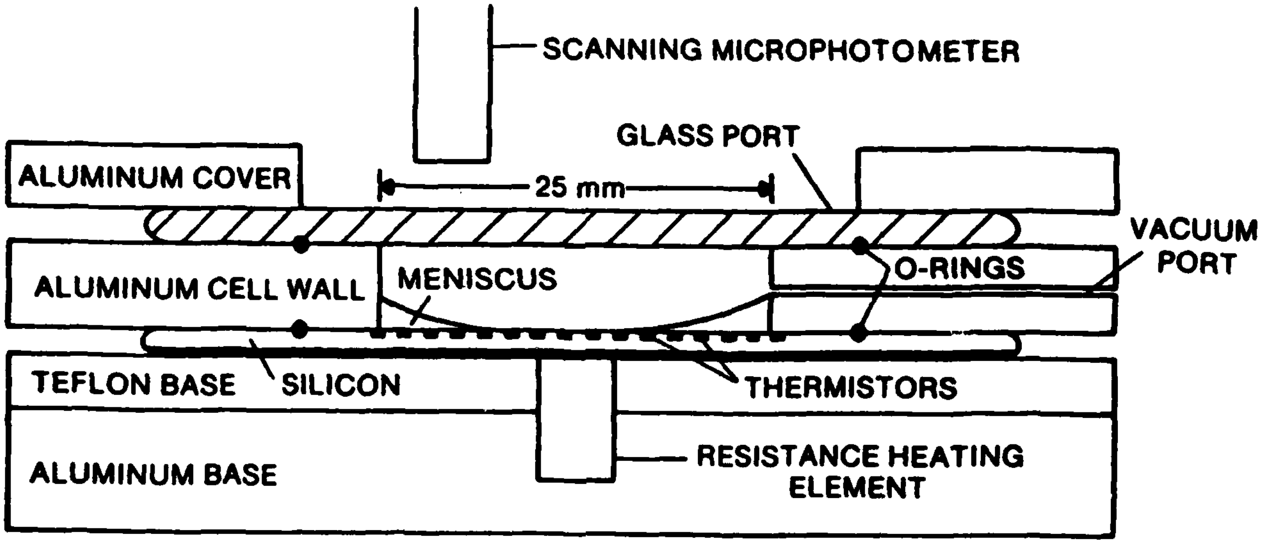
[3] Wayner, P.C., Jr., and Parks, C.J., "Effect of Liquid Composition on Enhanced Flow Due to Surface Shear in the Contact Line Region: Constant Vapor Pressure Boundary Condition," Presented at 23rd National Heat Transfer Conference, Denver, CO, Aug. 4-7, 1985. Printed in "Multiphase Flow and Heat Transfer", Editors: V.K. Dhin, J.C. Chen, O.C. Jones, ASME HTD-Vol. 47, pp. 57-63, 1985.

[4] Parks, C.J., and Wayner, P.C., Jr., "Fluid Flow in an Evaporating Meniscus of a Binary Mixture in the Contact Line Region: Constant Vapor Pressure Boundary Condition," Preprint # 39e, 1985 Annual Meeting of American Institute of Chemical Engineers, Chicago, IL, Nov. 10-14, 1985.

FIGURE 2

ACCOMPLISHMENTS

1. THE FOLLOWING SMALL CIRCULAR HEAT TRANSFER CELL WAS DESIGNED AND BUILT:



2. THE CELL DESIGN IS BEING TESTED FOR RESPONSE TO:

   a. VOLUME OF LIQUID CHARGE
   b. EXTERNAL HEAT INPUT
   c. LIQUID COMPOSITION
   d. EXTERNAL HEAT SINK
   e. PRESSURE OF NONCONDENSIBLES

3. SMALL TEMPERATURE SENSORS ARE UNDER DEVELOPMENT

4. TWO MODELING PAPERS WERE SUBMITTED FOR PRESENTATION

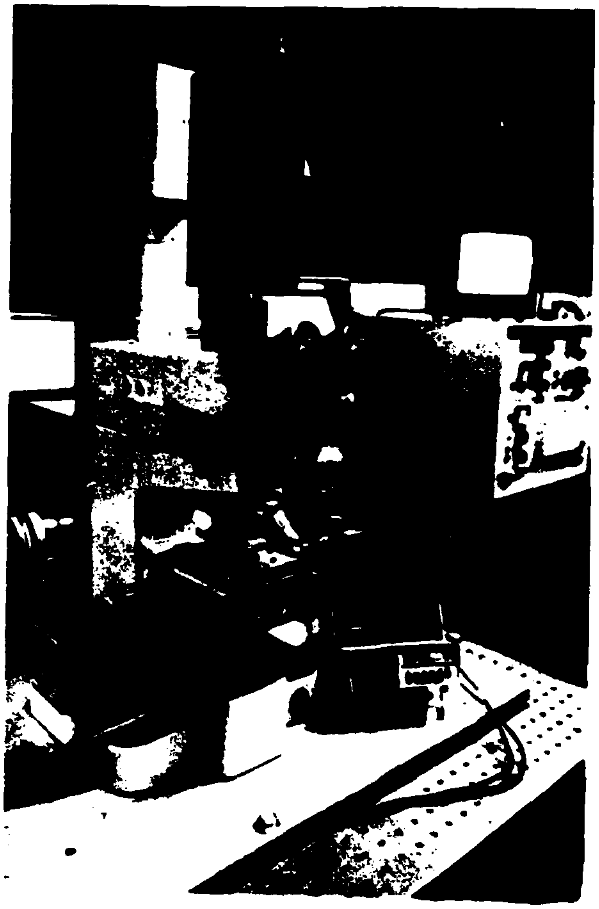


FIGURE 3

FIGURE 4

4. PUBLICATIONS

4(a) Wayner, P.C., Jr. and Parks, C.J., "Effect of Liquid Composition on Enhanced Flow Due to Surface Shear in the Contact Line Region: Constant Vapor Pressure Boundary Condition," in Multiphase Flow and Heat Transfer, Editors: V.K. Dhir, J.C. Chen, and O.C. Jones, ASME HTD - Vol. 47, pp. 57-63, 1985.

4(b) Kiewra, E. and Wayner, P.C., Jr., "Small Scale Thermosyphon for the Immersion Cooling of a Disc Heat Source," In preparation for AIAA/ASME Thermophysics and Heat Transfer Conference, Boston, MA, June 2-4, 1986.

5. PROFESSIONAL PERSONNEL

Peter C. Wayner, Jr., Principal Investigator
Edward Kiewra, Graduate Research Assistant
Linda Gerhardt, Graduate Research Assistant (Part-time)
Muralidhar Tirumala, Graduate Research Assistant (Part-time)

6. INTERACTIONS

(1) Wayner, P. C., Jr., "Effect of Interfacial Phenomena on Contact Line Heat Transfer," Paper 58, 1985 AFOSR/AFRPL Chemical Rocket Research Meeting, Lancaster, CA, March 18-25, 1985.

Wayner, P.C., Jr., and Parks, C.J., "Effect of Liquid Composition on Enhanced Flow Due to Surface Shear in the Contact Line Region: Constant Vapor Pressure Boundary Condition," Presented at 23rd National Heat Transfer Conference, Denver, CO, Aug. 4-7, 1985.

Parks, C.J., and Wayner, P.C., Jr., "Fluid Flow in an Evaporating Meniscus of a Binary Mixture in the Contact Line Region: Constant Vapor Pressure Boundary Condition," Preprint # 39e, 1985 Annual Meeting of American Institute of Chemical Engineers, Chicago, IL, Nov. 10-14, 1985.

(2) Meeting with E.T. Mahefkey (AFWAL/POOC) J.E. Beam (AFWAL/POOC), and R. Ponnappan at Wright-Patterson Air Foce Base, Ohio, 22 July 1985. Discussed research direction and general problems associated with heat pipe research at Wright-Patterson Air Force Base.

7. Analyzing use of research heat transfer cell as small thermosyphon for immersion cooling of electronic heat source.

8. None

END

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